Holston Army Ammunition Plant,
Producer Gas Plant
(Holston Ordnance Works)
Plant A (Area A)
Kingsport
Sullivan County
Tennessee

HAER No. TN-10A

PHOTOGRAPHS

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WRITTEN HISTORICAL DATA

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HISTORIC AMERICAN ENGINEERING RECORD

HOLSTON ARMY AMMUNITION PLANT,
PRODUCER GAS PLANT
(HOLSTON ORDNANCE WORKS)
HAER No. TN-10A

Location: Plant A (Area A),
Holston Army Ammunition Plant,
Kingsport,
Sullivan County, Tennessee.
UTM: 17.361260.4043480
Quad: Kingsport, Tennessee-Virginia

Date of Construction: 1943

Present Owner and Occupant: U.S. Army

Present Use: Manufacture of producer gas

Significance: Holston Army Ammunition Plant (HSAAP) was constructed during World War II for the manufacture of the military high explosive Composition B, and its chief ingredient RDX. In addition to these products, HSAAP also manufactured a number of its own raw materials, including, by means of coal gasification, a furnace fuel known as "producer gas." In almost continuous operation since its construction in 1943, the Producer Gas Plant contained 12, up-draft, "producer" units, which represented the most common type of producer gas technology.

Producer gas plants enjoyed their greatest vogue in the United States during the 1920s, when approximately 12,000 installations were in active industrial use. After this peak period, producer gas waned in popularity, primarily because of competitive pressures from natural gas and fuel oil. By 1948, there were less than 2,000 plants in operation, and the number continued to decline during the next three decades. When the "energy crisis" of the mid-1970s revived industrial interest in producer gas technology, it was discovered that HSAAP had one of the few active facilities remaining in the country.

Although only a subsidiary element in the total HSAAP manufacturing program, the

Producer Gas Plant is historically significant as a rare, intact, operating example of a once common industrial process.

Historian: Jeffrey A. Hess, April 1986

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SITE ORIENTATION

Holston Army Ammunition Plant (HSAAP) is a government-owned, contractor-operated installation constructed during 1943 for the manufacture of the military, high explosive Composition B and its chief ingredient RDX. The installation consists of two separate plants -- "Area A" and "Area B" -- located about four air miles apart on the Holston River in northeastern Tennessee (see HAER Photo Nos. TN-10A-7, TN-10A-8).[1] The two plants are connected by above-ground chemical pipelines and an inter-plant railroad (see HAER Photo Nos. TN-10A-12, TN-10A-13). Area A presently occupies about 120 acres in the heart of the manufacturing district of the City of Kingsport in Sullivan County. It produces raw materials for, and processes by-products from, Area B, which is situated westward and upstream on about 5,900 acres in rural suburban Hawkins County.

Rectangular in plan, Area A is bounded by undeveloped land on the north, U.S. Highway 95 on the east, the Holston River on the south, and the factory complex of the Tennessee Eastman Corporation on the east. Area A currently contains about two dozen buildings. Most of these structures were originally designed for the production of acetic anhydride, a liquid compound used in the manufacture of RDX at Area B (see HAER No. TN-10B).

The Producer Gas Plant (also known as "Building 10") is located in the east-central section of Area A. By means of coal gasification, it manufactures a synthetic fuel known as "producer gas," which is piped to two Acetic Anhydride

Manufacturing Buildings (Buildings 7 and 20) situated immediately to the north. Since the Producer Gas Plant has always been an integral part of a larger manufacturing program, an analysis of its operation requires an understanding of the total system. We will therefore briefly review the development and function of HSAAP in general and Area A in particular.

HISTORICAL BACKGROUND

In June 1940, shortly after the fall of France, President Roosevelt established the National Defense Research Committee (NDRC) to mobilize the nation's academic community for "research on the mechanisms and devices of warfare." In time, the NDRC would sponsor hundreds of research projects running the gamut from amphibious vehicles to rocket propellants. But initially it focused its attention on promising new technologies developed by the British, and this was particularly true in the area of high explosives.[2]

During the 1930's, British strategists had learned that German submarine hulls were being strengthened to withstand anything short of a direct hit by a conventional, TNT-loaded depth charge. To counter the U-boat threat, the British Admiralty began seeking a more effective explosive, and its first choice was cyclonite. Discovered as early as 1899, cyclonite was known to be almost twice as powerful as TNT -- but also several times more sensitive to shock, which precluded its use in conventional ordnance. By the late 1930's, however, British scientists at the Armament Research Department at Woolwich Arsenal had determined that cyclonite could be sufficiently desensitized for

munitions by combining it with wax, plasticizing oils, or TNT. As a security measure, the British rechristened cyclonite as "Research Department Explosive," or RDX. With a similar flair for anonymity, they chose the name of "Composition B" for the desensitized mixture of RDX (60%), TNT (40%), and wax (about 1%) that was to be widely used in Allied naval ordnance during World War II.[3]

For its most typical combat use, Composition B was combined with aluminum powder at specialized "loading plants" to form the explosive "Torpex," which was particularly effective in torpedos and depth charges. Indeed, Torpex torpedos were of such supreme strategic importance that tbey were carefully rationed by the Allies during the early years of the war:

> Originally issued to submarines with the best record of kills, the new product was distributed throughout the submarine fleet as fast as production permitted. Ship sinkings increased, and [reports were received] that Torpex torpedos were able to break vessels in two. Comparative tests with captured enemy munitions showed that neither the Germans nor the Japanese possessed explosives as powerful as Torpex.[4]

Composition B played a particularly crucial role "in winning the Battle of the Atlantic, [which was] acknowledged by both the United Nations and the Axis alike as the most important single phase of the war." Composition B also "in great measure paved the way for the invasion of the European continent and for the final destruction of the Japanese war effort."[5]

Although the British were the first to tame cyclonite, they were less successful in devising an efficient means for mass producing it. The method developed at Woolwich Arsenal, and first employed on a large scale at

Bridgewater, England in the summer of 1941, involved a simple batch process for the nitration of hexamine by concentrated nitric acid. Calling for 11 pounds of strong nitric acid for every pound of RDX produced, the Woolwich method required the construction of an enormous, on-site, nitric-acid works, which made the process extremely expensive to implement and operate. While the Bridgewater plant was still under construction, the British encouraged the newly created NDRC to investigate a cheaper method of manufacturing RDX. The NDRC took up the challenge, and in November 1940, it selected Werner E. Bachmann, an organic chemist at the University of Michigan, to work on the project.[6]

Bachmann had no previous experience with munitions, and as he later declared, his "heart sank" at the prospect of working on an explosives project. Despite his personal distaste for the work, Bachmann threw himself into the study with such energy that within three months he had developed a new RDX-production process, involving the nitration of hexamine by a mixture of strong nitric acid and ammonium nitrate, with acetic anhydride added to serve as a dehydrating agent that drove the reaction to completion. Bachmann's discovery reduced the total nitric-acid requirements of the Woolwich method by fully 85% while doubling the RDX yield from hexamine. The new process, however, did have one drawback: it released, as a by-product, substantial quantities of weak acetic acid contaminated with RDX. Before the Bachmann method could become a practical manufacturing technique, it was necessary to devise a means of purifying the acetic acid, concentrating it, and reconverting it to acetic

anhydride. The search for the solution to this problem led the NDRC to the Tennessee Eastman Corporation of Kingsport, Tennessee.[7]

A wholly-owned subsidiary of the Eastman Kodak Company of Rochester, New York, the Tennessee Eastman Corporation was a leading producer of both acetic anhydride and cellulose acetate, which it manufactured into synthetic yarn. In developing its cellulose-acetate facility, Tennessee Eastman had engineered an acetic-acid recovery system that seemed applicable to the Bachmann process. In November 1941, the NDRC requested Tennessee Eastman to join its RDX task force, and three months later, the company reported that it had worked out a feasible acid-recovery procedure. The firm was then asked to design and operate two pilot plants in Kingsport: one to manufacture RDX according to the Bachmann method, and the other to combine RDX and TNT into Composition B. Both plants were in production by the end of April 1942. Highly impressed with the company's expeditious handling of the pilot projects, the NDRC recommended that Tennessee Eastman be selected to design and operate HSAAP, the country's first and only large-scale, Bachmann-method, RDX installation. A contract to this effect was signed by Tennessee Eastman and the United States government in June 1942.[8]

The Kingsport area was selected as the site for HSAAP primarily because it was the manufacturing base of the Tennessee Eastman Corporation, which would serve as contractor-operator of the new facility.[9] The site also satisfied the following basic criteria that governed the selection of other World-War-II

explosives plants:

(1) availability of suitable labor without major housing projects;

(2) proximity to a main railroad line;

(3) availability of adequate electric power;

(4) ample supply of water for processing;

(5) availability of extended, isolated tracts for explosives manufacturing and storage;

(6) a location at least 200 miles from coastal waters and international borders as a defense against enemy attack.[10]

When the government began its acquisition of land for HSAAP in the summer of 1942, the Area-A site, immediately adjacent to the Tennessee Eastman Plant in Kingsport, was an unoccupied, industrially-zoned tract with no standing structures. The Area-B site in rural Hawkins County was predominantly crop and pasture land that had long been used for dairying.[11] Construction work on HSAAP commenced in the summer of 1942, under the general supervision of the U.S. Army Corps of Engineers, which created a special "Holston District" to administer the project. The Corps launched the project by letting two major contracts. The first went to Tennessee Eastman Corporation for "general layout of the plant, design of the manufacturing buildings, deaign and procurement of manufacturing equipment, and finally operation of the plant." The second contract was awarded to the New York architectural and engineering firm of Fraser-Brace Co., Inc., which had just completed a series of design and construction contracts for the expansion of the Weldon Springs Ordnance

Works, a sprawling TNT plant in Missouri.[12]

Fraser-Brace agreed to serve as general contractor and project manager, and assumed direct responsibility for "all construction and equipment installation, all procurement (other than manufacturing equipment), and all design of temporary utilities and structures." For its principal subcontractor on the HSAAP project, Fraser-Brace selected the Boston architectural and engineering firm of Charles T. Main, Inc., which had previously handled the construction of Camp Edwards in Massachussets. At the HSAAP site, the Boston firm was responsible for the "design of roads, railroads, bridges, utilities, magazines and all buildings other than manufacturing, as well as field layout and field inspection."[13] By dividing design responsibility among three firms, the Corps of Engineers had hoped to promote flexibility and speed. In practice, however, the project was plagued by persistent confusion at the construction site, exacerbated by "an element of friction" between Fraser-Brace and its Boston associate.[14]

In June 1943, as HSAAP was nearing completion, the War Department authorized a 40-percent increase of the installation's production capacity for Composition B. Two months later, this change order was ammended to provide for a 100-percent increase.[15] Since the expanded production quotas necessitated modifications in the original design of buildings and equipment as well as some new construction, work crews remained at the site until mid-March 1944, when "the project was finished, cleaned up and 100% in the hands of the

operators."[16] At this time the Corps of Engineers took inventory of the new installation and counted a total of 610 buildings. Of this number, 48 were located at Area A.[17]

In terms of its design, Area A closely resembled the neighboring factory complex of the Tennessee Eastman Corporation. The most obvious similarity was in the unadorned, utilitarian construction of the manufacturing buildings, which displayed exposed reinforced-concrete frames, brick curtain walls, and standard, industrial steel sash.[18] Although the use of brick was generally considered to be too expensive for wartime, munitions-plant construction, local conditions made it an acceptable material for HSAAP:

> Several of these buildings might have been built of all concrete, but lumber was exceedingly scarce and brick was used to save not only steel but form lumber. Brick was available in ample quantities for immediate delivery from a plant near Kingsport. An adequate number of capable bricklayers also was available, making cost of brick construction not excessive . . . .[19]

But the greatest similarity between the two plants was in chemical engineering. When Tennessee Eastman was first incorporated in 1920, it was intended to be a manufacturer of raw materials for its parent company, Eastman Kodak, in Rochester, New York. Setting up shop in an abandoned wood-distillation plant in Kingsport, the newly formed subsidiary produced acetic acid and acetic anhydride, which Eastman Kodak converted into cellulose acetate, the base for safety film. In 1930, Eastman Kodak transferred its entire cellulose acetate program to Kingsport, and Tennessee Eastman began building new facilities that incorporated a number of improvements in the manufacture of acetic acid and

acetic anhydride.[20] These new processes served as a model for Area A, which was designed to produce acetic anhydride, a primary ingredient in the manufacture of RDX.

In the early 1940s, the generally accepted method of producing acetic anhydride was to dehydrate "glacial," or concentrated, acetic acid.[21] This method was well suited for HSAAP because the RDX production lines at Area B released, as a by-product, substantial quantities of dilute acetic acid that could serve as the starting point for acetic anhydride manufacture. The weak acid from Area B was shipped to Area A in tank cars over an inter-plant railroad; it was then delivered to the Acid Concentration Plant (Building 2) for conversion into glacial acetic.[22]

Although dilute acetic acid could have been concentrated by simple distillation, the heat requirements were too prohibitive for large-scale industrial use. A more feasible method used "azeotropic distillation," which was pioneered by British chemists in the 1920s and adopted, with modifications, by Tennessee Eastman for its cellulose acetate plant during the 1930s. Briefly, azeotropic distillation employed an "entraining" liquid that was added to the dilute acid in order to "bind" the water into a special compound known as an "azeotrope" that boiled away at a lower temperature than the general acid-water mixture. Because of the differential boiling points, distillation procedures could then be used to remove the water and concentrate the dilute acid. With only minimal loss, the entraining fluid was recovered

from the waste water and continuously recycled.[23] Designed with a daily production capacity of 3.2 million pounds of glacial acetic, the Acid Concentration Plant employed an azeotropic process patented by Tennessee Eastman.

Since the glacial acetic acid produced from the Area-B dilute acid was insufficient to meet the installation's total requirements for acetic anhydride, Area A also had the capability to manufacture new acetic acid. Until the 1930s, almost all glacial acetic produced in the United States was by the destructive distillation of wood. In 1935, however, Tennessee Eastman began experimenting with a new British procedure for producing acetic acid by catalytic methods from ethyl alcohol.[24] This procedure was adopted at Area A in the Catalyst Building (Building 4) and Acid Production Plant (Building 3). The new acid was then concentrated into glacial grade at the Acetic Acid Concentration Plant (Building 2) by the previously described azeotropic method. The new-acid operation was designed with a daily production capacity of 200,000 pounds of glacial acetic.

Production of glacial acetic acid was the first step in the manufacture of acetic anhydride. In converting acid into anhydride at Area A, Tennessee Eastman implemented essentially the same system used at its own plant in Kingsport. Briefly, this method entailed heating glacial acetic acid in the presence of a catalyst so that it "cracked," or decomposed, into water vapor and a colorless gas called "ketene." Next, ketene was "scrubbed" with fresh

glacial acetic acid to form a crude mixture of acetic anhydride and dilute acetic acid. This crude solution was then refined and separated into pure anhydride and glacial acetic by repeated distillation in a rectifying column.[25]

In the original design of Area A, the anhydride operation focused on two principal structures: Building 7 prepared the crude anhydride solution and Building 6 refined it. In terms of basic equipment, Building 7 contained 32, gas-fired, "cracking furnaces" and eight "scrubbing trains"; and Building 6 had nine rectifying columns.[26] The doubling of HSAAP's RDX production quota in the summer of 1943 increased the installation's demand for acetic anhydride, which was satisfied by the construction at Area A of Building 20, containing 16 cracking furnaces and eight scrubbing trains. After the completion of this new facility in 1944, Area A comprised "the largest known acetic anhydride plant in the world."[27]

As was true for many privately owned, large industrial plants of the period, Area A generated most of its own utilities, purchasing only electric power from the regional grid of the Appalachian Electric Power Company. Filtered water from the Holston River was supplied by the Area-A Filter Plant (Building 9); steam for process and comfort heating by the coal-fired Steam Plant (Building 8). In addition, Area A manufactured its own fuel to operate the cracking furnaces in the Acetic Anhydride Production Buildings (Buildings 7 and 20). The need for this last operation was dictated by both geography and

economics. The Kingsport area had no supply of natural gas, and fuel oil, given wartime scarcities, was prohibitively expensive. The only alternative fuel in close proximity and abundant supply was coal, which was unsuitable for direct use in the cracking furnaces. Coal, however, was highly suitable as a raw material for the production of a feasible, synthetic fuel known as "producer gas."

Coal gasification in "producer gas plants" reached the height of its popularity in the United States in the 1920s, especially in industrial areas lacking oil and natural gas. The technology was relatively uncomplicated, yielding "the cheapest artificial gas per B.T.U. that can be made from solid fuel."[28] The one major drawback with producer gas was its comparatively low BTU rating, or "heat value," which meant that a greater volume of the gas was required to maintain a furnace at a given temperature than several other types of fuel. Large gas mains and a substantial pumping system were unavoidable aspects of the operation. For these reasons, producer gas was rarely distributed over great distances. But it was highly economical for use in compact industrial plants, such as Area A.[29]

The HSAAP Producer Gas Plant was designed, under subcontract with Tennessee Eastman, by Semet Solvay Engineering Corporation of New York (see HAER Photo Nos. TN-10A-7 through TN-10A-10). First placed in operation in May 1943, the plant was expanded the following year in order to meet the increased production requirements for acetic anhydride. It remained in service until August

1945, when all HSAAP facilities were shut down and "laid away."[30]

In April 1949, HSAAP was reactivated as a production facility under the contract-supervision of the Holston Defense Corporation, a newly formed subsidiary of Eastman Kodak. Initially, production activities focused on the reworking of surplus stocks of Composition B, which involved only a minimal use of Area B. But as the Korean War got underway, most of the facilities at Areas A and B were mobilized for new production. HSAAP has remained in continuous operation since the Korean Way, expanding and contracting its production schedules according to the dictates of military requirements. Although the RDX and Composition B manufacturing program at Area B has experienced a number of process improvements, there has been relatively little change in the acetic anhydride opcration at Area A. The most significant modification occurred during the Vietnam War, when the goverment phased out the production of glacial acetic acid, relying instead on outside vendors to supply the chemical.[31]

The operation of the Producer Gas Plant remains virtually the same as during World War II, which, in recent years, has brought the plant a good deal of unexpected attention. During the 1920s, when producer gas enjoyed its greatest American vogue, there were approximately 12,000 producer gas plants in active use, primarily in the steel and glass industries. After this peak period, producer gas waned in popularity, largely because of "severe competition [from] natural gas and fuel oil." By 1948, there were less than

2,000 bituminous gas producers in operation, and the number continued to decline during the next three decades.[32] When the energy crisis of the mid-1970s revived industrial interest in producer gas technology, it was discovered that HSAAP had "one of the few gas producer facilities in operation in the United States."[33] Although the Producer Gas Plant plays only a subsidiary role in HSAAP's overall manufacturing program, it is historically important as a rare, intact, operating example of a once-common industrial process.

PROCESS DESCRIPTION OF THE PRODUCER GAS PLANT

Producer gas is the generic name for a manufactured fuel consisting primarily of carbon monoxide and nitrogen, with smaller amounts of carbon dioxide and hydrogen, and trace amounts of oxygen and various hydrocarbons (such as methane, ethane, and ethylene). The caloric value of the fuel largely depends upon its combined content of carbon monoxide and hydrogen, which generally account for about 40 per cent of the total volume. The remainder of the mixture is mostly nitrogen and carbon dioxide. Since these two compounds are non-combustible, producer gas has a relatively low caloric rating, usually averaging between 135 and 180 BTU per cubic foot. In contrast, the heat value of natural gas is normally about 1,000 BTU per cubic foot.[34]

The high nitrogen content of producer gas is an unavoidable consequence of the manufacturing process. As a standard text on the subject explains:

> [Producer gas] is made by blowing air or a mixture of air and steam through an incandescent fuel bed. The oxygen of the air combines with

> the carbon in the fuel bed to produce carbon monoxide and some carbon dioxide, while the steam in the entering blast combines with the carbon. . . to produce carbon monoxide and hydrogen. The nitrogen of the air passes through the fuel bed unchanged and appears in the final product.[35]

Although the use of steam is not required in theory, it serves an important practical purpose. By lowering the temperature of the fuel bed, the steam reduces the likelihood of "clinkering," or fusing of ash, and thereby allows a more perfect combustion of the carbon. It also enriches the final product by liberating hydrogen.[36]

The producer gas process was first discovered in 1832 by Achilles Christian Wilhelm Friedrick von Faber du Faur, director of the Wurtemberg Government Iron Works in Wasseralfingen, Germany.[37] Despite the antiquity of the process and the relative simplicity of the chemistry involved, the manufacture of the gas remains as much an art as a science. The main problem is that the carbon source, usually bituminous coal, is subject to considerable variation in chemical composition. In order to produce uniform gas from heterogeneous coal, the operators of a producer gas plant must constantly monitor the combustion of the fuel bed, modifying steam and air intake as required. Although pressure and temperature gauges are of significant assistance, success depends on an experienced eye that can correctly interpret visual changes in the fuel bed.[38] The following observation of a producer gas engineer in 1922 holds true for the HSAAP plant today:

> Satisfactory gas cannot be made by purely mechanical means. In fact, a very high degree of skill is required in the successful operation of a gas-producer plant. . . . Uniform results call for uniform gas, and uniform gas can only be produced by the exercise of skill and everlasting vigilance backed by a broad experience. . . . The problems of getting the

> right kind of men to take charge of these plants and of keeping down the cost of the gas to a reasonable figure are most difficult.[39]

The central apparatus in the manufacture of producer gas is a brick-lined, steel-plate, fire box known as a "producer." Producers are generally categorized, according to the direction of the air intake blast, as "up-draft," "down-draft," or "cross-draft" models. In American industry, the up-draft producer was the "simplest and commonest type."[40] The conventional design featured a tall, cylindrical steel shell resting in a flared, water-filled "ash pan," which created an air-tight seal. The metal surrounding the hottest part of the fuel bed was often water-jacketed. Pressurized, steam-saturated air was introduced into the bottom of the shell, and coal was fed into the top to form a deep fuel bed, kept at a uniform level by the action of a revolving, water-cooled, "rabble arm," or poker. As the moist air flowed upward through the incandescent fuel bed, it reacted with the carbon to create producer gas, which was removed under vacuum at the top.[41] Ash from the fuel bed fell downward into the ash pan, where it was removed. In the earliest designs, the ash was simply shoveled out of the ash pan. Later, a mechanical ash-removal system was developed "by rotating either the producer shell or the [ash] pan":

> The ash normally flows out of the shell and sets itself up according to its angle of repose. By rotating either the shell or pan and placing an obstruction (plow) in the path of the ash the angle of repose is disturbed, the ash builds up in front of the obstruction and is removed by spilling over the edge of the pan.[42]

The producer design adopted for the HSAAP gas plant was, in all respects, a conventional, water-jacketed, steel-plate, brick-lined, up-draft system (see

HAER Photo No. TN-10A-11). Standing about 16 feet tall with an interior diameter of approximately 9 feet, the unit employs a rotating ash pan, with a stationary plow, to mechanically remove ash (see HAER Photo No. TN-10A-6). Coal is introduced through the top of the producer through a pocketed, rotating drum assembly (see HAER Photo No. TN-10A-2), which also activates the revolving rabble arm inside the producer. The ash pan at the bottom and coal-feed drum at the top are both powered by individual electric motors. The gas plant contains a total of 12 producers, each "rated at a maximum of 2,850,000 cubic feet of gas per day (on a 24 hour basis) from the gasification of a maximum of 24 tons of bituminous coal."[43]

The 12 producers are housed in the main section of the gas plant known as the "Producer Building." Four stories high and rectangular in plan, the building measures approximately 90 feet east-west, and 50 feet north-south (see HAER Photo Nos. TN-10A-7 through TN-10A-9). Except for a wood-frame, gable-roofed, coal-feed house on the top story, the building features an exposed, reinforced-concrete structural system consisting of six bays without exterior walls. The open plan is intended for ventilation, an essential feature in a plant that produces large quantities of carbon monoxide. The building is divided along its longitudinal, east-west axis into two mirror-image production assemblies, each containing a row of six producers, one per bay.[44] The bottom of each producer rests on the flat slab of the first floor (See HAER Photo No. TN-10A-6) and the top protrudes through the slab of the second floor (see HAER Photo No. TN-10A-2). A coal chute connects the producer to its

respective coal bin on the third floor, which is supplied with fuel by electric-powered conveyor apparatus on the top level.

Bituminous coal for the gas plant is delivered by railroad to a track-side dumping area near the southwest corner of the Producer Building (see HAER Photo No. TN-10A-6). Dumped into track-level grates, the coal falls into a reinforced-concrete, underground, "bunker room," surmounted by a small wood-framed, shed-roofed structure. An electric-powered, inclined conveyor elevates the coal from the bunker room to a four-story, wood-frame, gable-roofed "distribution tower," which, by means of an overhead conveyor, delivers the coal to the top floor of the Producer Building (see HAER Photo Nos. TN-10A-1, TN-10A-10).

Coal is only one of three ingredients necessary for the manufacture of producer gas at HSAAP. The other two are air and steam. Each producer is equipped with its own moist-air feed system consisting of a steam duct supplied with pressurized steam from the Area-A Steam Plant; a steam-powered turbine-and-fan unit for pressurizing ambient air; and a "saturation column" that mixes the two ingredients and feeds them into the bottom of the producer (see HAER Photo No. TN-10A-10). The manufactured gas is drawn off under vacuum at the top of the producer and circulated first through an adjacent, brick-lined dust collector, which removes fine ash, and then through a water-filled pitch trap, which removes heavy tar (see HAER Photo No. TN-10A-3). The gas then enters a common collector main that runs along the

outside of the building between the second and third levels, servicing the full row of producers. There are separate collector mains on each side of the building, with operator access provided by a flat-slab mezannine platform (see HAER Photo No. TN-10A-4). Inside the collector mains the gas is water-flushed by means of hollow cone sprays to remove still more of the tar. Each collector main then feeds the gas into a separate, steel "primary cooling tower" at the west end of the mezzanine, where the fuel is once again cleaned by water sprays.

The movement of the gas from the producers to the primary cooling towers is accomplished by vacuum created by an exhauster system housed in a flat-roofed, two-story Exhauster Building adjoining the west elevation of the Producer Building. Measuring approximately 60 feet east-west by 25 feet north-south, the structure has an exposed reinforced-concrete frame with slab flooring, brick walls, and industrial steel sash (see HAER Photos TN-10A-7 through TN-10A-9). The first floor houses toilets and pumping stations. The second floor contains a master gauge board for monitoring gas pressure and temperature, and three exhauster units, one for the east-side collector main, one for the west-side, and one for "back-up." Each exhauster unit consists of a large centrifugal fan operated by a steam turbine fed by the Area-A Steam Plant. The fan sucks in the gas from the primary cooling tower and then blows it out to a "secondary cooling tower," where it receives its final cleaning by water spray. Still under positive pressure from the exhauster system, the gas is piped to the Acetic Anhydride Manufacturing Buildings to fuel the cracking

furnaces.

The "scrubbing" operations in the collector mains and cooling towers generate a large volume of tar-contaminated water, which flows by gravity into ground-level decanters on the north and south elevations of the Exhauster Building (see HAER Photo Nos. TN-10A-7 through TN-10A-10). In the decanters the liquid separates into tar and "liquor" fractions, which are separately removed by pumps on the first level of the Exhauster Building. The liquor is pumped through cooling coils adjoining the west elevation of the Exhauster Building (see HAER Photo Nos. TN-10A-1, TN-10A-7), and then recirculated in the scrubbing trains. The tar is pumped through a steam-traced line to the Area-A Steam Plant, where it serves as fuel for the boilers. The tar from the pitch traps is also burned in the Steam Plant. Too thick for pumping, it is manually shoveled from the traps and barreled for delivery (see HAER Photo TN-10A-3).

At full-scale production during World War II and the Korean War, the gas plant operated 11 producers on a three-shift, 24-hour basis. One producer was always held in reserve as a back-up. Today, HSAAP's manufacturing schedule requires the full-time operation of only two producers, which are rotated every three months from the west-side production assembly. The east-side assembly is in "stand-by," scheduled to replace the other half for a four-year period beginning in 1987. The operating crew consists of a two-person, eight-hour shift, with an extra "swing man" during the day.[45] Generally, one

operator is stationed in the Exhauster Building, monitoring the gauge board. The other attends to the producers and "clean-up" trains, visually checking the fuel bed, activating tar and liquor pumps, disposing of ash, and removing pitch from the traps.

NOTES

1. The two sections of HSAAP were officially designated as "Plant A" and "Plant B," but ever since World War II, they have commonly been referred to as "Area A" and "Area B." Originally, the installation itself was known as "Holston Ordnance Works." The present name, Holston Army Ammunition Plant (HSAAP), dates from 1963. It is used throughout this report for the sake of brevity and clarity.

2. On the formation of the NDRC, see Baxter, pp. 14-25, 119-123, 451.

3. The British work with RDX during the 1930s is described in W. H. Simmons, "The Manufacture of R.D.X. in Great Britain," Industrial Chemist, 24 (July, 1948), 429-430; R. C. Burton, "The Origin of Holston Army Ammunition Plant," Speech before Rotary Club of Kingsport, Tenn., Sept. 10, 1975 (Kingsport: n. pub., 1975), n.p., in Palmer Room, Kingsport Public Library. On the use of RDX in naval ordnance, see Buford Rowland and William B. Boyd, U.S. Navy Bureau of Ordnance in World War II (Washington, D.C.: U.S. Government Printing Office, n.d.), pp. 204-207; Constance McLaughlin Green and others, The Ordnance Department: Planning Munitions For War (Washington, D.C: Office of the Chief of Military History, Department of the Army, 1955), p. 463.

4. Buford and Boyd, p. 206.

5. Ellen Crawford, "Full Story of HOW Product," Kingsport Times-News, December 9, 1945. The standard military history of American munitions-plant construction during World War II notes: "superexplosives from the Holston plant were crucially important in sweeping Hitler's U-boats from the Atlantic and in pulverizing German war industries" (Lenore Fine and Jesse A. Remington, The Corps of Engineers: Construction in the United States [Washington, D.C.: Office of the Chief of Military History, United States Army, 1972], p. 596).

6. The use of the Woolwich method at the Bridgewater plant is discussed in Simmons, "The Manufacture of R.D.X. in Great Britain," Industrial Chemist, 24 (July 1948), (August 1948), (September 1948), 429-432,

530-544, 593-601. On the method's nitric-acid requirements, Simmons writes: "One of the most striking features of the Woolwich process for the manufacture of R.D.X. is the size of the acid plant necessary. . . . It had been learnt by experience that the production of 1 ton of R.D.X. required the addition of 0.86 tons hexamine to 11 tons of concentrated nitric acid. Of this 11 tons about 5 tons could be recovered as weak acid . . . and rather more than 4 tons by absorption of the nitrous fume produced in the process. Allowing reasonable process losses, it was clear that for each ton of R.D.X. there would be about 9 tons of weak nitric to reconcentrate, and rather more than 2 tons of new strong nitric acid to reduce" (p. 430). The initial involvement of the NRDC with RDX research is discussed in Baxter, pp. 255-256.

7. Bachmann's initial response to the RDX project is noted in Baxter, p. 256. The first published description of the Bachmann method is found in W. E. Bachmann and John C. Sheehan, "A New Method of Preparing the High Explosive RDX," Journal of American Chemical Society, 71 (May 1949), 1842-1845. The method's pros and cons are analyzed in Burton, n.p.

8. On Tennessee Eastman's production of cellulose acetate, see "Eastman Corp. Defies Slump," Knoxville Journal, June 4, 1933; "Chemical Wonderland," Oilways, 14 (June 1948), 1-5. The acetic-acid recovery problems involved in the manufacture of cellulose acetate are discussed in Alfred George Lipscomb, Cellulose Acetate (London: Ernest Benn Limited, 1933), pp. 77-101. For Tennessee Eastman's pilot-project work, see Burton, n.p. It should be noted that HSAAP was not the first RDX plant built in the United States. That honor belonged to the Wabash River Ordnance Works, a Woolwich-type facility constructed at Newport, Indiana during 1941-1943. Boasting the world's largest nitric-acid works, the Wabash River plant accounted for about one-tenth of American RDX production during World War II; its RDX lines were completely dismantled in the 1970s. See Baxter, p. 257.; William Voight, Jr., "The Ordnance Organization in World War II," pp. 312-315, unpublished, 1945, on microfiche, in AMCCOM Historical Office, Rock Island Arsenal; C.H. Carter, Jr. and others, "History of the Powder and Explosives Section, March 1943 to September 1945," unpublished report prepared for Ammunition Division, Office of the Chief of Ordnance, 1945, pp. 9-11, Appendix IV-33, on microfiche, AMCCOM Historical Office; "Holston Army Ammunition Plant, Historical Monograph Covering the Period 1 July 1942 Through 30 June 1963," unpublished report prepared by Holston Defense Corporation, 1963, p. 22, in Holston Defense Corporation Archives, HSAAP.

9. Voight, pp. 132-133; Burton, n.p.

10. Lenore Fine and Jesse A. Remington, pp. 134-137.

11. "It's a Long Way from a Pasture to Ammo Plant," Kingsport News, November 14, 1968.

12. Harry Englander, Building Holston Ordnance Works (New York: Fraser-Brace Engineering Co., Inc. 1946), pp. 15, 19, in Holston Defense Corporation Archives, HSAAP. See also Fine and Remington, p. 517.

13. The description of the various contracts is from "Construction Speeded Output of 'RDX,'" Engineering New-Record, 64 (July 25, 1946), 64. Fraser-Brace's work on the Weldon Springs plant is noted in Englander, p. 19. On Charles T. Main, Inc. and Camp Edwards, see Fine and Remington, p. 211.

14. Fine and Remington, p. 595.

15. Robert O. Bengis, "Super Explosive Program, RDX and its Components A, B, and C," vol. 2, n.p., unpublished, 1945, Box 333, Record Group 319, Records of the Army Staff, National Archives, Washington, D.C ; hereafter citied as RG 139, with the appropriate box number.

16. Englander, p. 47.

17. "Industrial Facilities Inventory, Holston Ordnance Works," vols. 1, 2, 3, unpublished report prepared by U.S. Army Corps of Engineers, Office of the District Engineer, Nashville, Tennessee, 1944, HSAAP Archives.

18. See photographs of the Tennessee Eastman plant in "Eastman Corp. Defies Slump," Knoxville Journal, June 4, 1933; "Eastman Kodak in Tennessee," Kingsport News, April 9, 1951; TEC News October 2, 1980, in Holston Defense Corporation Archives, HSAAP.

19. "Construction Speeded Output of 'RDX'," 67. Immediately after Pearl Harbor the Army Ordnance Department laid down strict rules for future munitions plant construction: "There is no excuse for masonry structures . . . where a light frame structure will serve the purpose. There is no excuse for the use of expensive materials where less costly ones will serve the purpose for the period of time for which the construction is being provided." By the spring of 1942, however, the nation was experiencing a critical lumber shortage which prompted Ordnance construction supervisors to permit the substitution of brick for wood "where the difference in cost and completion time was not excessive." On this matter of buildings materials, see Fine and Remington, pp. 517, 547.

20. "TEC First 60 Years -- Logs to Modern Technology," TEC News, July 17, 1980, in Holston Defense Corporation Archives, HSAAP; "Eastman Corp. Defies Slump"; Knoxville Journal, June 4, 1933; "Eastman Kodak in Tennessee," Kingsport News, April 9, 1951.

21. G. Benson, "New Acetic Anhydride Process," Chemical and Metallurgical Engineering, 47 (March 1940), 150.

22. The discussion of the Area-A acetic anhydride operation relies heavily on information provided the author by Henry Hurd, Holston Defense Corporation Superintendent of Organic Acids, during an on-site interview, April 13, 1983. Also helpful were "equipment layout" plans and daily production capacities for the various processes in "industrial Facilities Inventory," vol. 3.

23. On the development of the azeotropic distillation of acetic aid, see Lipscomb, pp. 77-88; R. Norris Shreve, Chemical Process Industries (New York: McGraw-Hill Book Company, 1967, 3rd ed.), pp. 620-621.

24. See "Making Acetic Anhydride from Petroluem Ethyl Alcohol," Oilways, 14 (June 1948), 3; "Complex Situation Impending in Acetic Acid Manufacture," Chemical and Metallurgical Engineering, 38 (January 1931), 38-39.

25. Lipscomb, pp. 93-98; "Making Acetic Anhydride from Petroleum Ethyl Alcohol," 3.

26. Building 6 also contained an azeotropic still. The thermal cracking of glacial acetic acid in Buildings 7 and 20 was never 100 percent efficient, and residual amounts of acetic acid were carried over into the ketene-and-water-vapor mixture. The dilute acid was separated from the ketene by condensing trains in Buildings 7 and 20, and piped into the azeotropic still in Building 6, where it was processed into glacial acetic acid. This concentrated acid was then piped back to Buildings 7 and 20, where it was used to scrub the ketene.

27. Bengis, vol. 2, n.p.

28. Raymond Foss Bacon and William Allen Hamor, American Fuels, vol. 2 (New York: McGraw-Hill Book Company, 1922), p. 914.

29. Basil W. Waring and John F. Foster, "Producer Gas," Economics of Fuel Gas from Coal, eds., John F. Foster and Richard J. Lund (New York: McGraw-Hill Book Company, 1950), pp. 15, 19.

30. Tennessee Eastman Corporation, "Historical Report of Holston Ordnance Works for the Sixth Period May 16, 1943, through June 12, 1943," p. 5, unpublished, Box A77, Record Group 156, Records of the Office of the Chief of Ordnance, National Archives, Suitland, MD (hereafter cited as RG 156, with the appropriate box number); "Historical Report of Holston Ordnance Works for the Ninth Period August 12, 1945 to September 8, 1945," p. 12, unpublished, Box A79, RG 156. Semet-Solvay Engineering Corporation was originally incorporated in Pennsylvania in 1895 as Semet-Solvay Company. In 1916, the firm was taken over by a New York company incorporated that same year with the same name. With manufacturing interests in steel, coal, and chemicals, Semet-Solvay was also a leader in coal gasification; the firm built "the first by-product

coke ovens in the United States in 1892." In 1920, Semet-Solvey was taken over by Allied Chemical & Dye Corp., a New York company incorporated that same year "to consolidate by stock ownership the control of a number of companies engaged in the production, manufacture and sale of chemical products." In 1947, Allied Chemical & Dye merged Semet-Solvay with other subsidiary holdings and subsequently disposed of the business. The successor to Semet-Solvay's coal-gasification interests is Wilputte Corporation of Murray Hill, New Jersey, which also was once a subsidiary of Allied Chemical & Dye. For further information, see Cooper, n.p,; "Allied Chemical & Dye Corporation, Moody's Manual of Railroads and Corporation Securities, Industrial Section, 1921 (New York: Poor's Publishing Company, 1921), pp. 977-987; "Allied Corporation," Moody's Industrial Manual, vol. 1 (New York: Moody's Investors Services, 1981), p. 634.

31. Susan S. Pridemore, "Holston Army Ammunition Plant, Unit History, 1943-1967," p. 5, unpublished, 1968, HSAAP Archives; "Holston Army Ammunition Plant Historical Monograph," p. 17. The information on the shut down of the Area-A acid operation is from author's interview with Hurd.

32. Waring and Foster, pp. 15-16.

33. Holston Army Ammunition Plant, "Annual Historical Review, 1 October 1978 - 30 September 1979," unpublished, HSAAP Administrative Archives.

34. John F. Foster, "Types and Characteristics of Fuel Gases," Economics of Fuel Gas from Coal, pp. 3-5. Chemical assays of the producer gas manufactured at Holston have yielded the following results: hydrogen, 14.47%; oxygen, 0.72%; nitrogen, 46.12%; methane, 1.90%; carbon monoxide, 28.87%; carbon dioxide, 7.50%; ethane, 0.27%; ethylene, 0.15%. According to these analyses, the gas is rated at 166.13 BTU per cubic foot; see Billy R. Steidham, Memo to R. A. Jackson on the Subject of "Heat Value of Producer Gas -- Area A," March 15, 1978, unpublished, Holston Defense Corporation Archives, HSAAP.

35. Waring and Foster, p. 13.

36. Bacon and Hamor, pp. 919-920.

37. Bacon and Hamor, p. 917.

38. This discussion of producer gas technology and its application at HSAAP is indebted to John Willingham, Supervisor of Area A Utilities, Holston Defense Corporation, who granted the author a lengthy interview and tour of the Producer Gas Plant on December 5, 1985. The study also relies heavily on George R. Cooper, Wilputte Corporation, "Operating Overview of a Producer Gas Plant (12 Machines) at Kingsport, Tennessee," unpublished

paper delivered at Fifth Annual International Conference on Coal Gasification, Liquefaction and Conversion to Electricity, August 2, 1978, University of Pittsburgh, photocopy in Holston Defense Corporation Archives, HSAAP.

39. Bacon and Hamor, p. 916.

40. B. J. C. van der Hoeven, "Producers and Producer Gas," Chemistry of Coal Utilization, vol. 2 (New York: John Wiley & Sons, 1945), p. 1659.

41. Waring and Foster, pp. 16-17.

42. Van der Hoeven, p. 1662.

43. Cooper, n.p.

44. According to Cooper (n.p.), the original plant was equipped with 9 producers and received 3 additional units in 1944, which is in agreement with contemporary commentary noting the expansion of the gas operation in that year (Bengis, vol. 2, n.p.). One of the machines was installed in the original building, and an addition was constructed on the east elevation to house the other two, new units (see HAER Photo No. TN-10A-8).

45. Personnel requirements at the HSAAP gas plant conform to general labor estimates by Waring and Foster (p. 21) for a similar-sized operation.

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PROJECT INFORMATION

This project was part of a program initiated through a memorandum of agreement between the National Park Service and the U.S. Department of the Army. Stanley J. Fried, Chief, Real Estate Branch of Headquarters DARCOM, and Dr. Robert J. Kapsch, Chief of the Historic American Buildings Survey/Historic American Engineering Record, were program directors. Sally Kress Tompkins of HABS/HAER was program manager, and Robie S. Lange of HABS/HAER was project manager. Building Technology Incorporated, Silver Spring, Maryland, under the direction of William A. Brenner, acted as primary contractor, and MacDonald and Mack Partnership, Minneapolis, was a major subcontractor. The project included a survey of historic properties at Holston Army Ammunition Plant, as well as preparation of an historic properties report and HAER documentation for 13 buildings. The survey, report, and documentation were completed by Jeffrey A. Hess, historian, Minneapolis and Robert C. Mack, architect, Minneapolis. The photographs were taken by Robert A. Ryan and Bruce A. Harms of Dennett Muessig, Ryan, and Associates, Ltd., Iowa City, Iowa. Drawings were produced by Robert Ferguson of MacDonald and Mack Partnership, Minneapolis and John Palmer Low, Minneapolis.